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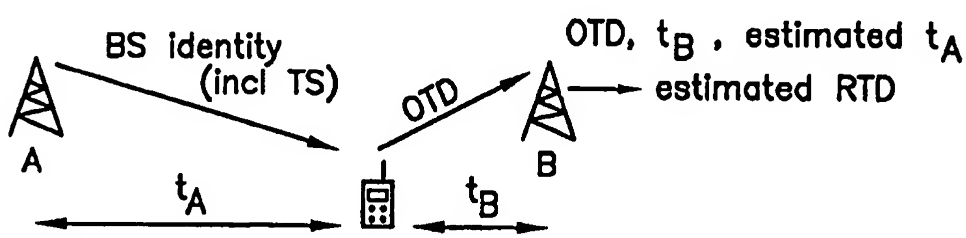
(54) Title: A BROADCAST CONTROL CHANNEL STRUCTURE FOR WIDEBAND TDMA



(57) Abstract

A mobile communication system and method for determining relationships between cells within an area including non-neighboring cells. The invention makes use of relatively strong coding of base station identifiers, substantially synchronized idle frames, and broadcast control channels which are transmitted on designated time slots for different co-channel cells within an area. The invention allows cell relation and synchronization information to be determined efficiently and reliably to allow for system performance improvements.

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A BROADCAST CONTROL CHANNEL STRUCTURE FOR WIDEBAND TDMA

FIELD OF THE INVENTION

The present invention relates generally to mobile communication systems. More particularly, the present invention relates to synchronization, handover, and cell relations in a cellular mobile communication system.

BACKGROUND OF THE INVENTION

In known wireless communication systems, radio resource management algorithms such as power control and dynamic channel allocation are provided to optimize the use of system resources (spectrum, power, etc.).

Many such algorithms can benefit from knowing the relations between cells - for example, how much disturbance exists from other cells in a system. Cell relationship information allows more centralized algorithms to be used, and can improve algorithm performance.

One way of obtaining cell relations is to let the mobile stations (MSs) in the system monitor the control channels transmitted from different base stations (BSs). By registering the strength and identity of received base station control channels, the cell relations can be deduced. Base station identification is typically performed by determining the base station identity codes (BSIC) that are transmitted by the base stations on their respective control channels.

In the GSM system, mobile stations are capable of identifying neighboring base stations by decoding the encoded BSIC. Each BSIC is a non-unique code transmitted by each base station on time slot 0 of the control channel frequency, every 10th TDMA frame.

Because the mobile stations are not synchronized with neighboring cells, each mobile station must listen for eight time slots of the control channel, to make sure that time slot 0 (and thus BSIC information) is decoded. This is made possible by introducing idle frames. FIGs. 1A and 1B show exemplary successive idle frames, 13

frames apart in a GSM system, where mobile stations transmitting on time slots ts0-ts7 transmit control channel information C, idle slots I (i.e., no transmission), and signaling information S. It will be appreciated that time slots ts0 and ts1 are typically reserved for control channel information C, and that no mobile station uses those time slots for transmission of data or signaling information S. In the GSM system, not all mobile stations in a cell have their idle frames at the same time. During a mobile station's idle frame, the mobile station is silent - that is, the mobile station does not transmit information. Because different mobile stations have different idle frames, other mobile stations may transmit during one mobile station's idle frame. For example, in FIG. 1A, mobile stations communicating on ts2, ts4, and ts6 are idle, while mobile stations on ts3, ts5, and ts7 send signaling information.

As BSIC information is sent only once every 10th TDMA frame, the GSM control channel multi-frames and traffic channel multiframes are designed so that the idle frame will be adjusted to correspond with different types of control channels, and eventually correspond to the BSIC information (sliding multiframes). This complicated procedure requires up to 10 seconds for a mobile station to decode the BSICs of the six best neighbors.

In GSM, the reliable determination of cell relations is limited for at least three reasons.

A first reason is that the coding of the BSIC is relatively weak in GSM. To be decoded by a base station, the carrier-to-interference ratio (C/I) for the control channel signal must be relatively high. While this is often the case for neighboring base stations, for base stations further away the carrier strength (C) is usually lower and the interference (I) is usually higher. The worst case is when two co-channel BSICs are received which are relatively equal in signal strength. Then the C/I ratio on this channel is around 0 dB, and it is impossible to decode either of the two BSICs.

A second reason is that in GSM, problems arise when a mobile station tries to decode the BSIC of a co-channel cell (a cell that is using the same control channel as the mobile station's serving cell). Then, the serving base station can become a source of interference. The reason for this is that while one mobile station is idle in this

frame, other mobile stations in the same cell may receive control channel information or signaling information in this frame, creating interference on these slots.

A third reason is that the BSIC identities used in GSM are only 6 bits long; therefore, the same combination of control channel frequency and BSIC are used by multiple cells in a system. Thus, a BSIC decoded on a certain control channel frequency cannot automatically be associated with a specific cell.

While other solutions for obtaining path loss cell relations exist, they are complex, can only decode a very limited number of identities, or require central control of the network.

Therefore, it would be desirable to provide a communication method and system which allow cell relations in a relatively large area to be quickly, easily, and reliably determined.

SUMMARY OF THE INVENTION

The present invention provides for a communication system and method for fast identity decoding. The present invention allows cell relations to be obtained for a relatively large area in an efficient way.

The present invention makes use of one or more of the following: strongly coded base station identities, substantially synchronized idle frames to reduce interference from traffic channels; and increasing the "reuse distance" for control channels by placing the control channels on designated time slots in different co-channel cells.

The present invention is preferably implemented in a slot and frame synchronized system. A method for automatically obtaining approximate, local synchronization is also provided.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention can be more fully understood upon reading the following Detailed Description in conjunction with the accompanying drawings, in which like reference indicia are used to designate like elements, and in which:

FIGs. 1A-1B are exemplary consecutive idle frames in a GSM communication system;

FIG. 2 is a representation of three base stations communicating with three mobile stations over a common frequency;

FIG. 3 is a representation of broadcast channel allocation according to one embodiment of the present invention;

FIG. 4 is a diagram of an area of cells using the broadcast channel allocation scheme of FIG. 3;

FIGs. 5A-5B are diagrams showing an ideal case and a more practical case, respectively, of control channel allocation;

FIG. 6 is a exemplary identity burst transmitted from a base station over a control channel according to an aspect of the present invention; and

FIG. 7 is a diagram showing a mobile station determining cell relation information and providing synchronization information according to one embodiment of the present invention.

DETAILED DESCRIPTION

The present invention will be described assuming a mobile TDMA system where the base stations transmit only control channel or signaling information (occupying one or more time slots) during idle frames. The system can either be a packet switched system or a circuit switched system where all mobile stations in a cell have substantially synchronized idle frames. It will be appreciated, however, that the invention can be applied to other types of communication systems. It is also assumed that the BS identities are unique within at least some area which includes non-neighboring cells.

According to one aspect of the present invention, base station identities are encoded stronger than in a conventional (e.g., GSM) system. This makes it possible to decode the identities at relatively low C/I levels. Even with increased coding, it is still desirable to reduce interference, and thereby increase the C/I ratio. Therefore, according to a second aspect of the present invention, the interference from traffic

channels is reduced by substantially synchronizing the idle frames for all base stations in an area including non-neighboring cells. If perfect synchronization and zero propagation delays could be achieved with this area, interference would be eliminated. As a practical matter, local slot and frame synchronization between base stations within an area can substantially decrease interference.

It is also desirable to place the broadcast control channels for different co-channel cells on designated time slots to substantially reduce interference from the broadcast channel of a serving cell. This is exemplified in FIG. 2, where three co-channel base stations, A, B and C use the same control channel frequency, but the broadcast information is transmitted on different time slots. This means that if the mobile station in cell C tries to decode the identities of A and B, it will not be disturbed by base station C's control channel information. Furthermore, it is possible to decode the identities of both base stations A and B in the same idle frame, as they transmit their respective identities at different times. The only interference comes from other cells using the same control channel frequency and time slot as A and B. Due to the high reuse that is obtained by placing the broadcast channels on designated time slots, this interference will be significantly weaker than interference in conventional systems.

FIGs. 3 and 4 give an example of the broadcast channel allocation in an area of cells which include non-neighboring cells. In this example, the traffic channel reuse is three, and the broadcast channel is spread over five time slots. This means that the broadcast channel is not reused within five traffic channel clusters, so the broadcast channel reuse is 15. The five base stations using the same frequency f_x are co-channel cells in different clusters. These base stations transmit on different broadcast channel time slots. It will be appreciated that the broadcast channel reuse is increased five times when the broadcast channel is spread over five designated time slots. FIG. 3 shows the broadcast channel allocation, where each of the different patterns represents one of the five clusters in FIG 4. The three base stations in a cluster can use the same broadcast channel time slot, since they use different frequencies. The different frequencies f_x, f_y, and f_z can be adjacent or non-adjacent frequencies. If the frequencies

are adjacent, different time slots can be used within the cluster to decrease adjacent channel interference.

During an idle frame, each mobile station chooses one frequency and decodes as many base station identity codes on it as possible. In the next idle frame, a new frequency is chosen. The frequency choice can be based on intermediate interference measurements, or, if the number of frequencies is not very large, the mobile stations can sequentially scan through all frequencies.

The invention is particularly useful in a wideband TDMA system with a relatively small number of carrier frequencies and a relatively large number of time slots on each carrier. In such a system, the mobile station can decode a relatively large number of identities in each idle frame. Because the number of frequencies is limited, the mobile station can decode all identities relatively quickly.

The results (the base station identities and signal strengths with which each base station identity code was received) are reported to the serving base station. The measurements from each base station can be reported to a central entity where the cell relations can be calculated and stored. The stored cell relations can be used for performing handovers in a quick and efficient manner. For example, the stored cell relations can improve automatic frequency planning and can be used to determine which potential new base stations can be measured for handover purposes. The information can also reduce the need for certain handover measurements.

An exemplary implementation of the present invention will now be described, assuming a wideband TDMA system, where each frequency carrier is divided into 64 time slots each of which is 72 ms long.

If perfect synchronization could be achieved with zero transmission delay, the mobile stations could decode an identity in each time slot, that is 64 identities per idle frame.

More practically, the control channels can be placed on, for example, every second time slot, as shown in FIGs. 5A-B, which represent the case where a mobile station attempts to decode the identities of two base stations, A and B, that have the same broadcast channel frequency f_1 but different time slots. The time shift between

the transmissions from base stations A and B represented in FIG. 5B is due to imperfect synchronization and propagation delay.

FIG. 5A is an ideal case in which the mobile station is able to decode both identities. In FIG. 5B, imperfect synchronization and different propagation times from the two base stations result in a time shift between the transmissions from base stations A and B, and also result in interference between the two broadcast channels. If one base station is relatively close and the other is relatively distant (i.e. the synchronization and propagation time difference is mainly due to the difference in transmission delay), the mobile station can decode the identity of the closer base station. Alternatively, if interference is caused by poor synchronization, the signals from different base stations may be of approximately equal strength, such that a mobile station will be unable to accurately decode any of the identities.

In this example, the synchronization and propagation time differences do not add up to more than one time slot. If the burst size is 72 ms, half of a 1 slot shift results from transmission delay difference, and the other half of the shift results from imperfect synchronization, there may be difficulties in decoding the identities of base stations further away than 11 km.

Depending on the degree of synchronization, the number of time slots on each carrier frequency used for control channel information can be varied. If, for example, control channels are placed on every eighth time slot in this 64 slot example, both the synchronization and the transmission delay difference requirements become less critical. The broadcast channel reuse is still high and the mobile stations can decode eight identities per idle frame. This is sufficient for handover purposes.

An exemplary identity burst for transmission on the broadcast channel slots is shown in FIG. 6. The identity burst contains a training sequence part and an information part (e.g., including BSIC and current time slot information). The identity burst can preferably be received and decoded in an environment with considerably lower C/N than what is possible in e.g. the GSM case, since the broadcast control channel structure according to the invention reduces most of the interference, but does not reduce noise. In other words, to decode BSIC from cells which are beyond the

neighboring cells, a more robust channel is desirable. The burst length in FIG. 6 is the same as a normal burst. There is no additional guard time needed, since there are guard slot(s) between the broadcast control channel slots.

The training sequence in the identity burst is relatively long, in order to allow capture of the identity burst and synchronization in low C/N environments. There can be either only one possible training sequence, or different training sequences in the TDMA slots. Different training sequences can be used for synchronization purposes, where the training sequence designates a slot number. In this case, the information part of the identity burst need not include current time slot information.

The information part of the identity burst preferably includes an encoded BSIC, where the code is a relatively low rate convolutional code or block code. For low C/N operation, a code rate of approximately 1/4 or less is desirable. A CRC code can also be encoded into the burst to allow for error detection. The receiver can use the CRC together with soft receiver metrics (e.g. decoder path metrics and C/I measures) to distinguish between correctly and incorrectly received bursts.

The identity burst is transmitted for each idle slot. If a mobile station can synchronize to a burst without successfully decoding it, the received signal can be stored and a second synchronization can be made at the next idle slot. The received signal from two or more idle slots can then be soft combined before a second decoding attempt is made. This allows for successful reception of identity bursts received at an even lower C/N ratio.

Referring now to FIG. 7, a mobile station is shown determining cell relations and providing synchronization information based on received identity bursts. The mobile station in FIG. 7 is served by a base station B, and decodes an identity burst from base station A, including the base station identity code and synchronization information for base station A. Since the mobile station knows the current time slot for the serving base station B, it can calculate an Observed Time Difference, OTD, for transmissions from base stations A and B, and forward the OTD to serving base station B. The relation between the OTD and the RTD (Real Time Difference) is

$$RTD = OTD + t_B - t_A$$

where t_A and t_B are the propagation delays from BSs A and B, respectively.

t_B and OTD are now known in base station B, and t_A can be estimated from geometrical considerations. Hence an estimate of RTD can be calculated in base station B.

If OTD is reported by the mobile station, and RTD calculated by the base station or a central processor each time an identity is decoded by a base station, large statistics on synchronization differences between different base stations can be obtained over time. It should be appreciated that the further away base station A is located from the mobile station, the less accurate will t_A be. Therefore, it is preferable to synchronize to closer base stations. It will be appreciated that this synchronization method can be used to achieve synchronization for any number of purposes, and can be used with or without the broadcast control channel scheme described above. To achieve synchronization, the mobile station receives and decodes identity and synchronization information from multiple base stations, and transmits this information to abase station for determining synchronization based on the decoded information (using, e.g., the OTD technique described above). If synchronization processing is performed locally in a base station, the base station can use the decoded information to adjust its own synchronization. If the synchronization processing is performed at a central location for multiple base stations, the base stations will be instructed from the central location as necessary to adjust synchronization.

If RTD values discussed above are needed for synchronization of neighboring base stations, special synch & identity bursts can be transmitted that contain both BSIC and a frame number. These can be transmitted at regular intervals in the TDMA frame structure. Since more bits (BSIC + frame number) are now transmitted, less coding is possible. This means that the synch & identity burst can be detected within a shorter range than the identity burst.

It will be appreciated that the invention provides a fast and efficient way to decode a relatively large number of base station identities in an approximately synchronized wideband TDMA system. This can be used for establishing cell

relations, to be used by long-term algorithms, as well as for improving the performance of short-term algorithms such as handover.

The broadcast control channel structure can significantly reduce interference on the broadcast channels if carefully constructed identity bursts are transmitted by the base stations. If synchronization information is included in the identity bursts, the system can autonomously perform approximate synchronization.

While the foregoing description includes numerous details and specificities, it is to be understood that many modifications can be made without departing from the spirit and scope of the invention, as defined by the following claims and their legal equivalents.

WHAT IS CLAIMED IS:

1. A mobile communication system, comprising:

a plurality of cells, at least some of which are not neighboring cells;

a plurality of base stations having base station identities which are unique within the plurality of cells, each base station serving a corresponding cell, wherein the base stations transmit broadcast control information on designated time slots; and

a plurality of receivers, each receiver determining one or more base station identities and signal strength measurements contained in an identity burst transmitted as broadcast control information during idle frames, and transmitting the determined results to the base station serving the each receiver.

2. The system of claim 1, wherein the base station identities are encoded prior to transmission from the base stations.

3. The system of claim 2, wherein the base station identities are encoded using a coding rate of approximately 1/4 or less.

4. The system of claim 1, wherein the base station identities are transmitted with synchronization information.

5. The system of claim 1, wherein the base stations transmit time slots in a substantially synchronized manner.

6. The system of claim 1, wherein the receivers include mobile receivers.

7. The system of claim 1, wherein the receivers determine base station identities by scanning a selected frequency during each idle frame.

8. The system of claim 5, wherein the base stations have substantially synchronized idle frames.

9. The system of claim 1, wherein the base stations transmit on different designated time slots.

10. In a cellular communication system including a plurality of cells, each cell being served by a base station having a base station identity which is unique within the plurality of cells, a method for determining cell relationships between a plurality of cells, comprising the steps of:

substantially synchronizing time slots for a plurality of base stations at least some of which do not serve neighboring cells;

transmitting broadcast control information from each of the plurality of base stations on designated time slots; and

determining, at a receiver, one or more base station identities and signal strength measurements included in the broadcast control information during idle frames, and transmitting the determined results to the base station serving the receiver.

11. The method of claim 10, further comprising the step of encoding the base station identities and transmitting each encoded base station identity from its associated base station during an idle frame.

12. The method of claim 11, wherein the step of encoding is performed using a code rate of approximately 1/4 or less.

13. The method of claim 10, wherein the base stations have substantially synchronized idle frames.

14. The method of claim 10, wherein the receiver is a mobile receiver.

15. The method of claim 10, wherein the step of determining is performed at the receiver by scanning a selected frequency during each idle frame.

16. The method of claim 10, wherein the base station identity includes synchronization information.

17. The method of claim 10, further comprising the step of storing the determined results from the plurality of base stations.

18. The method of claim 17, wherein the stored determined results are used for handover purposes.

19. A method for obtaining synchronization between a plurality of base stations in a mobile communications system, comprising the steps of:

decoding, at the mobile station, identity and synchronization information from the plurality of base stations, at least some of which do not serve neighboring cells; and

synchronizing the base stations based on the decoded identity and synchronization information.

20. The method of claim 19, wherein the step of synchronizing is performed by the steps of:

calculating, at the mobile station, an observed time difference between information transmitted from different base stations;

transmitting the calculated observed time difference to one of the different base stations; and

determining a real time difference between information transmitted from different base stations at the one base station.

21. The method of claim 19, wherein the identity and synchronization information are contained in an identity burst transmitted by each of the plurality of base stations.

22. The method of claim 21, wherein the synchronization information includes an identification of the time slot or frame number on which the synchronization information is transmitted.

23. The method of claim 21, wherein the synchronization information is derived from a training sequence transmitted in the identity burst.

24. The method of claim 19, wherein the identity and synchronization information is transmitted from the plurality of base stations during substantially synchronized idle frames.

25. The method of claim 19, wherein the identity and synchronization information from each of the plurality of base stations are transmitted on designated time slots.

26. The method of claim 19, wherein the identity information is unique for each of the plurality of base stations.

27. The method of claim 19, wherein each base station can adjust its synchronization based on the decoded identity and synchronization information.

TS0	TS1	TS2	TS3	TS4	TS5	TS6	TS7
C	C	I	S	I	S	I	S

FIG. 1A

TS0	TS1	TS2	TS3	TS4	TS5	TS6	TS7
C	C	S	I	S	I	S	I

FIG. 1B

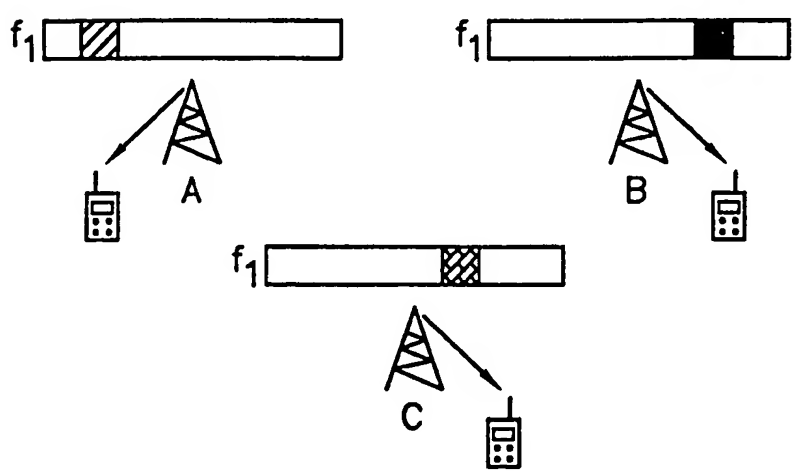

FIG. 2

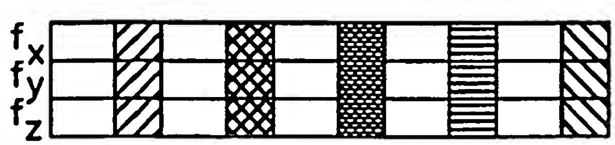

FIG. 3

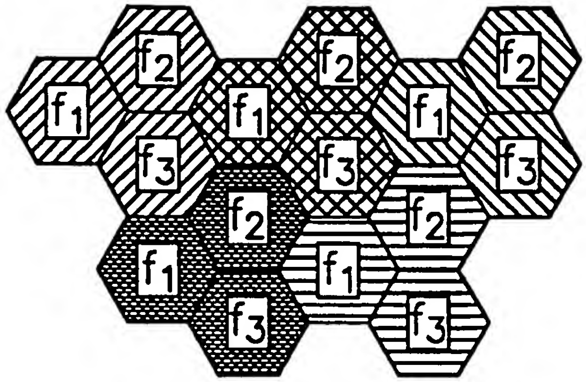

FIG. 4

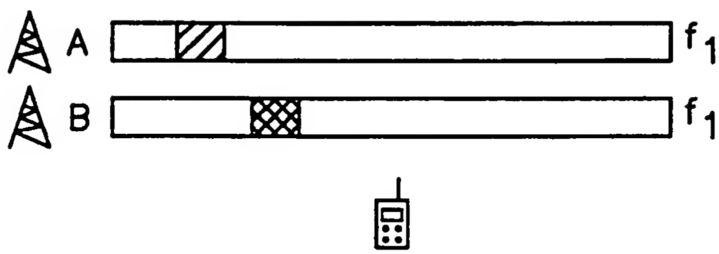

FIG. 5a

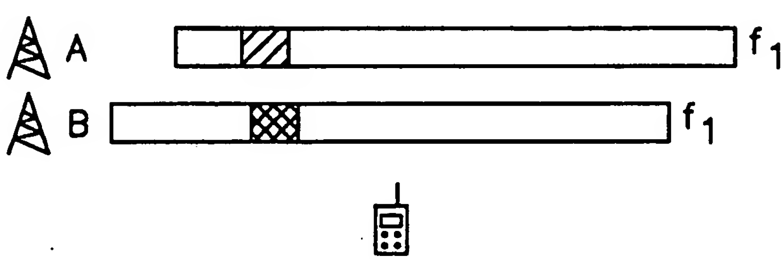

FIG. 5b


training sequence
information

FIG. 6

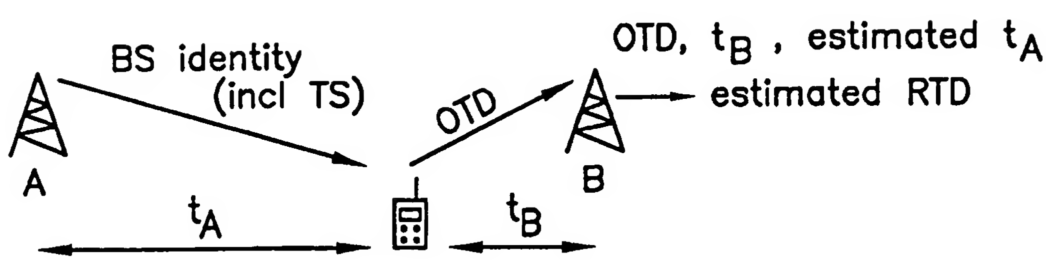
BS identity
(incl TS)
OTD
OTD, t_B , estimated t_A
estimated RTD
A
B
t_A
t_B

FIG. 7

INTERNATIONAL SEARCH REPORT

International Application No
PCT/SE 98/01752

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04B7/26

According to International Patent Classification (IPC) or to both national classification and IPC

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Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04B H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A		21-27

A	WO 96 19087 A (NOKIA TELECOMMUNICATIONS OY ;VAARA TOMI (FI)) 20 June 1996 see page 1, line 15 - page 2, line 18 see page 6, line 20 - page 8, line 22	1,10,19

A	WO 96 38014 A (ERICSSON TELEFON AB L M) 28 November 1996 see page 8, line 3 - page 9, line 1	1,10,19

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
5 January 1999	13/01/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Larcinese, A

1

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	MOULY ET AL: "The GSM system for mobile communications" 1993 , EUROPE MEDIA , LASSAY-LES-CHATEAUX XP002066677 see page 336, line 20 - page 339, line 10	1,10,19
A	"GSM 05.10 version 4.4.0" ETSI STANDARD,January 1994, pages 12-13, XP002066676 see the whole document	20

1

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